

Some Observations on the Feeding-habits of Fish and Birds, with special reference to Warning Coloration and Mimicry. By J. C. MOTTRAM, M.B. (Lond.). (Communicated by Prof. E. B. POULTON, F.R.S., F.L.S.)

(PLATE 5.)

[Read 1st March, 1917.]

MATERIAL for this paper has been extracted from a journal, wherein are recorded observations of the riverside habits, and especially the feeding-habits, of fish and birds during the years 1909 to 1915 inclusive; they were not collected with any special object in view, and were made in the British Isles and during one season in New Zealand.

The paper is divided into two parts: the first deals with observations which have a bearing on the hypothesis of Warning Coloration; the second with those which appear to throw fresh light on certain aspects of Mimicry.

PART I.

Feeding-Habits of Salmo fario, Linn. (the Brook Trout).

The fish is strictly carnivorous. Its food consists of small fish, crustaceans, molluscs, annelids, aquatic and floating insects. Vegetable matter was found on only very few occasions out of five to six hundred autopsies. In New Zealand, on one occasion, the stomach of a fish was filled with *Spirogyra*, Link; subsequently it was proved that the fish took the weed in order at the same time to capture a small Trichopteroous larva. The yellow bloom of the furze, *Ulex europæus*, Linn., was also taken on account of a small grub, probably Tineina. In this country pieces of Ribbon-weed, *Potamogeton*, Tourn., are taken in order to obtain *Simulium*, Latr., colonies, either larva or pupa. Sometimes small pieces of wood, of grass stems, and grass and other seeds are found in the alimentary canal; these will be accounted for subsequently.

When the fish are feeding on floating insects conditions are particularly favourable for detailed observation: the insect can be clearly seen and cannot be taken by the fish without a marked disturbance of the surface. The under-water feeding is less easily observed, but examination of stomach and intestinal contents gives reliable information.

The feeding-habits depend to a large extent on the quantity of the food-supply. In waters where food of all kinds is abundant, as in many chalk-streams, the fish, although they have the choice of many kinds of food,

always take a mixed diet. It is rare on opening a fish to find the remains of only one kind of food : in one part of the intestine will be found, for instance, snail-shells ; in another fish-bone, and in the stomach insect-remains. The arrangement of the food in the alimentary tract indicates that the fish take their food in batches, the remains of the various foods are more often than not unmixed and occupy different parts of the gut.

Observations in every respect confirm this : a fish picking up snails from the river-bed will never stop to take a floating insect ; fish taking floating insects will entirely ignore a shoal of minnows in the neighbourhood ; on the other hand, when a fish is taking minnows other foods are neglected. This hunting of one prey at a time is most clearly seen when the fish are taking floating insects. It is the rule in chalk-streams to observe fish taking only one species of insect when there are two or more on the water.

These observations indicate that fish are subject to what may be called a special appetite, as distinguished from a general one. When a fish is observed to be feeding on one insect and neglecting another, it cannot be concluded that there is more than a temporary difference in palatability between these two insects ; it is not unlikely that another fish may be seen feeding on the second insect and neglecting the first. There is some evidence that these individual and temporary preferences depend upon what food the fish has had in the immediate past ; if, for instance, the fish has recently fed upon insects, it will be more likely to take some other food when next hungry. In many rivers during early June *Ephemera danica*, Müll. (the May-fly), hatches out in immense quantities and the fish at once gorge themselves with it ; nevertheless, towards the close of the May-fly season, the fish may often be seen taking other food, whilst *M. danica* is hatching out in abundance the fish may even be seen taking smaller species of the Ephemeridæ or some species of Diptera.

Obs.—15. 6. 1813, R. Kennet, “ Found two trout taking ‘ Olive Dun ’ (sub-imago of *Baëtis vernus*, Curtis) and neglecting the May flies which were hatching out at the same time. Also saw several dace (*Leuciscus leuciscus*, White) feeding upon ‘ Reed Smuts ’ (*Simulium*, Latr.) and neglecting the May fly.”

It is well known to fly-fishermen that for some weeks after the May-fly season the fish more or less neglect insect diet : “ The May-fly carnival means a long interval, during which the rod may as well be put by, for the glutted fish take a ‘ cure ’ of at least three weeks, during which they abstain from insect-food of all descriptions ” (from ‘ Happy Hunting Grounds,’ by A. E. Gathorne-Hardy).

In some streams *Brachycentrus subnubilus*, Curtis, (Grannom) hatches out in immense quantities during April, and, in a similar way, the trout quickly satiate themselves with this insect.

A general survey of the feeding-habits of trout, where food is plentiful, brings out three distinct facts: (1) the fish prefer mixed diet; (2) fish feed upon one food at a time; (3) fish have a special appetite as apart from a general appetite.

In waters where food is scarce the fish only grow to a small size. Under these conditions their feeding-habits are entirely different: they take all food that comes within their reach, they are forced by general hunger to eat that which is supplied, they have no opportunity of exhibiting preference. Their method of taking food is shown on examination of their stomach contents; the following are two typical examples:—

“. . . Aug. 21, 1905, R. Lambourne, Great Shelford, part of river where food is scarce, stomach contents were 2 house flies, 2 bluebottles, 1 wasp, numerous reed smuts and other small Diptera, 2 shrimps, 1 snail.

“Sept. 10, 1910, Pennel burn, North Wales, stomach contents were 1 grasshopper, 2 wasps, 1 black beetle, several small species of Coleoptera, 1 large Ichneumon fly, 1 daddy-longlegs, 2 hoppers, 6 house flies, 2 caddises, numerous small Diptera, numerous red and black ants male and female, several duns and spinners (sub-imago and imago of Ephemera).”

Had observations been confined to such fish, conclusions would have been drawn that trout appear to have no preference for particular foods.

*Evidence that Trout recognize a Difference in Palatability between
different Food.*

In order to prove that fish do discriminate, a long series of observations must show that, although the fish take both foods, nevertheless, when they have the choice of both, they much more often take one than the other. During May the trout have often choice of two floating insects, the sub-imago of *Baëtis vernus*, Curtis (the “Olive Dun”), and the imago of *Bibio johannis*, Meig. (the “Black Gnat”). It will be seen that some fish are taking both insects, others the *Bibio* only, and others the dun. Each fish thus falls into one of the three classes: by observing a number of fish, distribution of feeding-habit is obtained, as in the following observation:—

May 16, 1910, “Black gnats and olive duns on the water from 10.0 to 11.30 A.M.: of 20 feeding fish, 11 were taking duns only, 7 black gnats only, and 2 were taking both flies.”

Similar observations made on many days and on different waters show that the dun, *Baëtis vernus*, is taken more frequently than the gnat, *Bibio johannis*. The number of fish taking both insects was found to depend on the stream on which the observations were made; where the food-supply is

scanty the fish most often take both insects, no doubt because their general appetite is very good. Neglecting this class of fish, the following figures were obtained:—Number of fish observed 201, fish taking only duns 149, fish taking only black gnat 52.

Similar observations indicate that the sub-imago of *Baëtis pumilus*, Burm. ("Iron Blue Dun"), is more palatable than *B. binoculatus*, Leach ("Pale Watery Dun"), and that the imago of the smaller Ephemeriidæ is more so than *Simulium* ("the Reed Smut").

Even these observations are not quite free from doubt, the relative prevalence of the insects may play a part, or one insect may be more easily captured than another, or more easily seen. Nevertheless, there is stronger evidence that fish do appreciate a difference in palatability. There are two species of the Ephemeriidæ, *Heptagenia sulfuria*, Müll. ("Yellow May Dun"), and *Leptophlebia marginata*, Eaton ("Turkey Brown Dun"), which are almost never taken by trout. A "Yellow May Dun" (*sulfuria*) has never been seen to be taken by a trout, though a great number have been observed floating down where fish were feeding. On two occasions considerable hatches of this insect were seen, but the fish left them alone.

Obs.—"Sept. 25, 1909, R. Teme, Eardistone, saw a good hatch of the 'yellow May dun' (*H. sulfuria*), many on the water at the same time; this is rarely seen; trout and grayling rising at other flies, but no fish feeding on the 'May dun.'

"Sept. 28, another hatch of the 'yellow May dun' (*sulfuria*), fish not taking the insect."

As regards the "turkey brown" (*L. marginata*), I have seen this insect taken on one occasion by two fish, one of which was captured and two recovered from the stomach.

Obs.—"10. 5. 1914, R. Lambourne, Newbury, a hatch of 'turkey browns' (*L. marginata*), saw two fish take these insects: killed one and recovered two from the fish's stomach; this is the first time I have seen this insect taken by fish."

It is the experience of anglers that these insects are very rarely taken. These two insects are among the less common species of the Ephemeriidæ, and it is possible that their scarcity may be a factor in causing them to be neglected by the fish; on the other hand, fish are often seen feeding on other species even when the hatch is very sparse.

There are two other insects which are almost immune from the attacks of trout, *Gerris thoracica*, Fabr., and *Velia currens*, Latr. ("water-skaters"). In the vast majority of trout-streams these insects abound, but I have never seen one taken by a fish; on two occasions I have recovered single specimens from the stomach. The taking of these insects has been observed by anglers on a few occasions. It is possible the fish neglect them because they are difficult to capture; they are very active, buoyant, and difficult to drown,

The only other animal which trout appear to avoid is the tadpole. In lakes and in still pools of most trout-streams tadpoles are found, but I have never seen trout feeding upon them, nor have they been recovered from the alimentary canal. On the river Exe, during 1911, a small pool was observed in which were four trout and tadpoles estimated to the number of two hundred: no diminution of the number was detected during four days. Similar observations were made in a hatch-hole on the river Lambourne at Shelford in 1910, during ten days, with similar result; the possibility of tadpoles dropping down from above was excluded. Nevertheless, on a few occasions anglers have observed trout to be feeding on tadpoles in waters where there was a scarcity of food. The colour of the tadpole deep black, its gregarious habits, its making no attempt at concealment, indicate that the animal is not much open to attack. It is also noteworthy that the vivid yellow of the "yellow May dun" (*H. sulfuria*) makes this insect a conspicuous object on the water; it is certainly more easily seen than any other of the smaller British Ephemeriidæ.

These observations indicate that trout do recognise a difference in palatability between different foods; also that the relatively unpalatable foods are occasionally devoured. No small animal which lives either in, or upon the surface of, fresh water has been observed to be entirely immune from the attacks of trout.

The feeding-habits of other fish, in respect of floating insects, is of considerable interest: *Thymallus vulgaris*, Nilss. (the Grayling), takes floating insects as freely as trout; *Leuciscus leuciscus* (the Dace) also feeds freely on floating insects; *Leuciscus cephalus*, Flem. (the Chub), in many streams, only feeds on floating insects during the "grannom" (*Brachycentrus subnubilus*) and "May-fly" seasons, or when an especially large hatch of some other insect occurs, in other streams it rises almost as freely as the dace; *Leuciscus rutilus*, Flem. (the Roach), is very seldom observed to be feeding on floating insects, but during the "May-fly" (*Ephemera danica*) season it not infrequently takes the sub-imago.

As will be seen, a similar sequence is found among the birds: some feed only upon the "May-fly" (*E. danica*), others take other water-insects as well, whilst others again feed freely upon almost every riverside species.

Before considering the significance of these conclusions with regard to warning coloration, some observations on the feeding-habits of birds will be described.

Cypselus apus, Ill. (Swift), *Hirundo rustica*, Linn. (Swallow), *Chelidon urbica*, Boie (Martin), and *Cotile riparia*, Boie (Sand-Martin), feed freely on the sub-imago of the Ephemeriidæ, either taking the insects whilst resting on the water or after they have risen into the air. It is rare to see a hatch of these insects without these birds hunting them, so much so that by watching

these birds the angler knows when to begin fishing; nevertheless, they occasionally become satiated with these insects. During the close of the "May-fly" (*Ephemera danica*) season it is by no means uncommon to see the swallows hunting over the fields whilst May-flies are hatching-out.

Obs.—"June 5, 1913, R. Kennet, Thatcham, whilst a good hatch of *E. danica* was on, swallows were hunting over the meadows to the windward of the river and were therefore not feeding on the 'May fly,' which for several days they have been eagerly devouring."

In contrast to their liking for the Ephemeridæ, they have only on a very few occasions been observed to take the "Black Gnat" (*B. johannis*): there evidently appears to be a distinct difference in palatability between these insects. A difference in the ease with which they may be captured cannot account for the selection, because the birds take other insects whose flight is quite as erratic as that of the "Black Gnat," and also the "Black Gnat" is often over the water in such dense swarms that the birds would have but to fly through them in order to obtain a mouthful, a method of feeding which they often employ for the capture of many small insects which swarm in the air.

Emberiza schœniclus, Linn. (the Reed-Bunting), is very adept at picking the sub-imago of the Ephemeridæ off the water; it in the same way feeds upon *Brachycentrus subnubilus* (the Grannom), and has never been seen taking *B. johannis* (Black Gnat).

Motacilla lugubris, Linn., *M. boarula*, Linn., and *M. rayi*, Bonap. (Wagtails), are commonly seen taking Ephemeridæ; on two occasions, during a double hatch of "Grannom" and "Olive Dun," it was noticed that the birds took the Ephemeridæ by preference, allowing "Grannom," close at hand, to pass untouched whilst flying several yards for a "Dun."

Obs.—"April 16, 1910, R. Lambourne, a mixed hatch of 'Grannom' and 'Olive Dun,' 11.0 A.M. to 1.0 P.M., a pair of *M. lugubris* feeding on both flies; when a dun was available it was always taken though 'Grannom' were often closer on the water."

A second observation with *M. rayi*, on the same river, was precisely similar.

A large number of different species of birds collect at the river-side during the "May-fly" season: Fringillidæ (Sparrow, Chaffinch, Greenfinch), *Sturnus vulgaris*, Naum. (Starling), Laridæ (Black-headed Gull and Common Tern), Anatidæ (Ducks), *Muscicapa grisola*, Linn. (Flycatcher), *Anthus pratensis*, Bechst. (Meadow-Pipit), Sylviidæ (Warblers), and other birds which are not, as a rule, observed feeding upon the smaller species of the Ephemeridæ. These observations indicate that the several British species of

Ephemeridæ could be arranged in an order of palatability, both for birds and fish, headed by *Ephemera danica*, as probably the most palatable, and *Heptagenia sulphurica*, as the least.

The habits of the Swift are of particular interest because of its great agility, and the great pace at which it hunts would undoubtedly enable it to take any flying insect—for instance, when feeding on the “May-fly,” the impact of bird and fly can be distinctly heard at a distance of ten to fifteen yards. I have seen them take white butterflies on two occasions.

Obs.—“7. 5. 1913, R. Kennet, swifts feeding on ‘May fly,’ many Pierines crossing the river: the bird caught one with the greatest ease and at once rejected it, the insect fell on the water and was not recovered. 15. 6. 1910, ‘swift’ took a small garden white at a single sloop, then passed behind a willow tree, out of view.”

These observations are recorded because they show that the birds could capture these butterflies did they care to. As a proof that much less agile birds are capable of capturing rapidly flying insects, it may be mentioned that on three occasions Sparrows have been observed amongst new-mown hay successfully chasing *Tryphaena pronuba*, Hübn. (Yellow Under-wing Moth); on two occasions small flocks of these birds were observed feeding in this manner for several hours. Wagtails on several occasions have been observed systematically hunting *Musca domestica*, Linn. (the House-fly), and *Scatophaga stercoraria*, Latr. (the Dung-fly).

The Significance of these Observations with respect to Warning Coloration.

It appears that whether or no an animal will prey upon another depends upon a number of factors, of which the following are the most important:—

(1) The animal's general hunger: a hungry trout will take all that comes within its reach, sometimes even tadpoles; a less hungry fish will only take the more palatable foods, whilst an almost satisfied fish will only take the most palatable.

(2) The animal's special hunger: trout, and less certainly birds, prefer a mixed diet, if an animal has lately become satiated with a particular food, then this food is temporarily lowered in the scale of palatability.

(3) The readiness with which a food can be gathered: animals difficult to capture will be neglected at the expense of those easy to take.

(4) The prevalence of a food-supply: trout, and less certainly birds, appear to concentrate their energies upon hunting one prey at a time; for this reason they will attack a prevalent prey in preference to a scarce one (it has been often observed that birds will feed upon insects when they are unusually abundant and which they have never before been seen to attack).

(5) The animals appreciate a difference in palatability. Possibly there are other factors which control the selection. It is obvious that in order to estimate the palatability of food all these determining factors must be taken into account.

It may here be mentioned that relative palatability may itself depend upon several factors, of which taste and digestibility are not necessarily the most important. The readiness with which the prey can be disposed of is an important one: for instance, when butterflies are attacked by small birds the large expanse of wing protects the small body, the insect is likely to be seized by one or both wings, when the bird shifts its hold in order to dispose of it the wing is momentarily released and the scarcely injured insect escapes, requiring to be recaptured; further, when the insect has been killed, the stiff dry scale-covered wings are difficult to swallow, and are, as a rule, removed before the body is eaten. It would appear that a butterfly is unpalatable in this respect, apart from taste. If warning coloration advertises unpleasant taste there seems no reason why it should not also advertise difficult disposal.

It is also conceivable that warning coloration may similarly advertise difficult capture; on the other hand, conspicuous coloration would give the hunter a good mark to follow. Inconspicuous coloration is of use during motion: a covey of grouse flying over heather can only be followed with the eye for a short distance; should there be a partially white bird among the covey it can be followed over the moors for a mile or so. Entomologists find some inconspicuous butterflies very hard to capture on the wing, not because of rapid flight, but because they are being constantly lost in the background.

The feeding-habits of birds upon butterflies is of special interest because selection by birds has been considered to be a factor in the production of mimicry in these insects. On this account, particular attention has been paid to the feeding of birds upon butterflies. Marshall (1) has collected together the records of the attack of birds upon butterflies up to the year 1909 and given reasons for the paucity of the evidence, which has been considerably increased since then. The evidence at present collected appears to show that—

- (1) Birds seldom feed upon butterflies;
- (2) They are less often attacked, and are less often found in the alimentary canal of birds, than are many other insects.

(Further evidence may, however, negative both these statements. Whenever accurate field-observations are made these instances of birds feeding upon butterflies are by no means infrequently recorded. Swynnerton has shewn that these insects are so broken up in the alimentary tract of birds that a careful microscopical examination is required for their recognition.)

It has therefore been concluded that on broad lines butterflies are less palatable than many other insects, and that their diurnal habits, relatively slow flight, and conspicuousness may be looked upon as warning characters.

The wings of butterflies, apart from pattern and coloration, are conspicuous on account of their large size (size is a very powerful factor as regards visibility), and also on account of their opacity (transparent wings are a great aid to concealment). Although butterflies as a whole may be less palatable than many other insects, it does not follow that among them there may not be difference in palatability, just as there is in the Ephemeroptera towards fish and birds; and just as butterflies may as a whole exhibit conspicuous (warning) characters so, among them, according to their palatability, some may exhibit more conspicuous characters than others. If animals can be arranged in an order of palatability, and if warning coloration and protective resemblance are the result of selection by enemies, then animals liable to attack should also form a series presenting all grades, from a most pronounced conspicuous coloration to a great protective resemblance, the intermediate forms showing something of both. Some evidence has been brought forward that this occurs in the Ephemeridæ. In a previous paper (5), the factors for conspicuous pattern were ascertained by experiment with artificial pattern, and it was shown that among Indian Lepidoptera some of the insects present all the factors for conspicuousness; others, some only; whilst others, only a few. Swynnerton (2) has shown that animals, which form the food-supply of any species, can be arranged in order from the most palatable to the least palatable; and opinion is expressed that animals bear some distinctive mark whereby a preyer can recognise and distinguish the relatively unpalatable from the relatively palatable. The "distinctive" coloration need not necessarily be very conspicuous. Unpalatable animals can afford to carry a conspicuous mark, but the relatively palatable can only carry one, which is to a small extent conspicuous, or one which is only displayed when concealment has failed.

This conception is similar to the author's, but is better in that, by replacing the term "warning coloration," it brings into line those slightly conspicuous characters which cannot be called "warning" characters. The conception presumes that preying animals have a memorising power of considerable magnitude, but this presumption does not appear to be always necessary: for instance, a very strong family likeness runs through long series of protected species of butterflies. Swynnerton says of this, "This can be accounted for by the advantage of maintained notoriety." If, however, a number of different butterflies present very conspicuous characters, they must be very similar in appearance, because the majority of the factors for conspicuousness must be present in each. Poulton (3), so long ago as 1887, observed that certain colours and patterns associated with unpalatability,

do constantly recur among insects, both in the larva and adult states. It follows that in this case unpalatability might be associated in the preyer's mind, not with a particular form, colour, pattern, or other character, but with conspicuousness. If a bird be given a conspicuous insect which it has never before seen it will be shy in attack; whereas when the insect is inconspicuous the bird's attack will be bolder. Variations in edibility may be associated in the preyer's mind with degrees of conspicuousness rather than with distinctive markings: many distinctive marks appear to be related to concealment rather than the reverse; nevertheless, as a working hypothesis, Swynnerton's conception may prove to be of considerable value.

(3) Birds have been observed sometimes to exercise no choice with respect to butterflies on which they are feeding. As has been already seen, the conclusion that they do not recognise a difference in palatability cannot be drawn.

(4) Birds have been sometimes observed feeding upon presumably protected butterflies, *Euploëines* and *Danaines*. Conclusions cannot be drawn that they are not relatively unpalatable; trout will sometimes feed upon tadpoles.

(5) Birds have on a few occasions (4) been observed to feed upon some butterflies, whilst neglecting others. This might be the result of a temporary special appetite of the bird, the difference in the ease of capture of the insects, or by a difference in the relative prevalence of the insects. Only after exclusion of these and other factors can it be concluded to be due to a difference in palatability.

PART 2.

Observations which show that Salmo fario mistakes other things for Floating Insects, and fails to distinguish Artificial Flies from Natural Ones.

As already mentioned, examination of the alimentary contents often reveals the presence of small pieces of wood, stick, grass-stem, and seeds, more especially grass-seeds. If a trout, which is feeding on floating insects, be observed over a long period, it will be seen often closely to examine many such small floating things; the majority of these the fish will neglect, a few will be taken into the mouth to be at once rejected, a small proportion is swallowed. There can be no doubt that the fish mistakes these things for the insect on which the fish is feeding at the time, and it may be concluded that its vision is not very acute. If the fish is feeding on one particular insect, as is most often the case in chalk-streams, mistakes are much more seldom made than when the fish is feeding on any floating insect which the stream may bring down.

The following are samples of the observations :—

Obs.—“ *March 30, 1911, lake Okeraka, New Zealand, stomach contents of trout were four grasshoppers, two cicadas, and three short pieces of stick of about the same length and thickness as the grasshoppers.*

“ *July 21, 1911, R. Kennet, Newbury, stomach contents were many ‘Pale Watery Duns’ (*Baëtis binoculatus*) and three grass seeds similar in size to the bodies of the insects.*

“ *July 5, 1909, R. Lambourne, Shefford, watched a fish for half an hour taking ‘blue-winged olives’ (*Ephemerebella ignita*, Poda) and ‘Reed Smuts’ (*Simulium*), fish always examined any small floating object which at all resembled the insects; on more than a dozen occasions such things were mouthed, and twice, evidently swallowed.*”

More certain evidence that trout are easily deluded is provided by the fact that the dry-fly fisherman is able to kill fish with crude floating imitations of the natural insects made of fur and feather. Dry-fly fishing consists of floating over the fish and making to rest on the surface of the water, a dry artificial insect in imitation of the natural one on which the fish has been observed to be feeding. In streams which are little fished the fish are easily deluded; but, in heavily fished waters, they become educated and are able, on close inspection of the insect, to detect the counterfeit. This education is the result of the fish having been either caught and returned, or hooked and lost on many occasions. The Plate (Pl. 5) shows a series of artificial insects photographed against a high light, as the fish see them. It illustrates the roughness of their resemblance to the natural insects. The artificial insect may be looked upon as an unpalatable insect mimicking a palatable one, and the facts show that a crude mimicry is of considerable power for delusion.

Observations which indicate that Birds mistake inanimate things for Flying Insects, and the Angler’s Fly floating on the water for Insects similarly situated.

If *Muscicapa grisola* (spotted flycatcher) or any of the species of swallows or martins be watched, over a long period of time, whilst they are feeding on flying insects, it will be noticed that not infrequently the birds start out from where they are resting, or alter their line of flight, in order to capture small pieces of feather, seed-plumes, leaf-scales, chaff, or other light bodies floating in the air, which they obviously mistake for flying insects; as a rule, closer inspection shows them their mistake. Sometimes the object is taken in the bill and subsequently dropped; or very occasionally it appears to be

swallowed. The following are details of some of the observations, given to show that the above statement is not open to doubt.

Obs.—"3. 6. 1913, watched a spotted flycatcher feeding upon small flying insects, chiefly gnats, observations extending over half an hour, bird seen to set out after small pieces of feather, chaff, &c. on three occasions, and a fourth time the object was taken in the bill.

"13. 5. 1914, swallows feeding upon 'olive duns,' bird took small piece of feather which was not seen to be discarded.

"18. 4. 1910, wagtails feeding upon 'Grannom,' on several occasions bird made for small floating objects resembling the insect, and twice picked these off the surface of the water, then dropped them."

Whilst making such observations, it was noted that the birds often flew long distances after passing insects, as much as twenty yards, and that many of the mistakes were then made.

The dry-fly fisherman's evidence that birds are easily deluded, is very clear. Swallows, martins, and swifts very commonly pick the artificial insect off the water, when an imitation of one of the Ephemera is being used. Two typical experiences are given:—

Obs.—"5. 7. 1909, R. Lambourne, Great Shelford, 3.0 to 4.0 P.M., hatch of 'Blue-winged Olives' (*Ephemerella ignita*), swallows picking insects off the water as well as taking them in the air, my artificial 'Blue-winged Olive' was repeatedly picked off the water and carried for a yard or two in the air, by both swallows and martins: so persistent were the birds that they interfered with the fishing.

"20. 4. 1913, hatch of 'Grannom,' 11.0 to 12.30, black-headed bunting picking insects off the water, on two occasions bird mistook my artificial insect."

Similar mistakes have been personally witnessed in the case of the following birds: *Motacilla rayi*, *M. boarula*, *Sterna* (a tern in New Zealand), *Anthus pratensis*, *Acrocephalus schænobæus*, Newton, *Caprimulgus europæus*, Linn., *Anser* (domestic duck), *Podiceps fluviatilis*, Degl. & Gerbe, and species of Bat (undetermined).

It is clear therefore that birds, like trout, frequently mistake crude imitations for living insects.

The Importance of these Observations with respect to certain Aspects of Mimicry.

It has been shown that a crude resemblance suffices to delude both birds and trout. It would appear therefore highly probable that if one insect only slightly resembled another, which the bird was avoiding, then the mimicking insect would, to some extent, be also avoided. The fact that birds have been observed to begin their attack from considerable distances would help to give value to a crude resemblance; because at such distance all details of pattern and coloration (especially during motion) cannot be seen.

These considerations are of some importance, because it is difficult to conceive how mimicry can have had a beginning, except by a variation of considerable magnitude; further, it has been thought that birds would be able to see through a disguise, unless it were good. However, the observations which have been recorded indicate that both birds and fish are easily deceived, and that a crude resemblance would be likely to give a mimicking insect some protection, and especially because birds often begin their attack from such a distance that many details of pattern and coloration are invisible. On the one hand, a bird may allow to pass at twenty feet a mimic which is only a poor imitation of a protected species; on the other hand, at two feet, a good imitation may be necessary for immunity from attack. It would follow that, although a poor imitation may gain some protection, a good mimic would gain more; so that from a rough resemblance, a good resemblance could conceivably be built up by the agency of selection by birds. There is ample evidence that butterflies, as a whole, are less palatable to birds than many other groups of insects. An examination of their form, pattern, coloration, and habits shows that they exhibit several characters which must render them, relatively to other insects, conspicuous in Nature. Nevertheless, if butterflies, as a whole, be considered to present some warning characters, it obviously does not follow that, within the group, there may not be degrees of palatability associated with variations in the amount of warning coloration, and that therefore there may not be also within the group mimicry.

SUMMARY.

Attention is especially directed to two aspects of the relations between prey and preyed upon.

First, that there are many factors which determine whether or not, at any particular time, one animal will prey upon another, of which relative palatability is only one. In order, therefore, to demonstrate a difference in palatability between various foods, all these determining factors must be taken into account.

Second, that observations indicate that both birds and fish are deluded by rough resemblances to the insects upon which they are at the time feeding.

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PLATE 5.

ARTIFICIAL INSECTS. (Halford's patterns.)

The Explanation is printed at the foot
of the Plate.



ARTIFICIAL INSECTS (HALFORD'S PATTERNS)

- FIG. 1. Male imago of *Baëtis pumilus*, Burm. ("Iron Blue Spinner").
 „ 2. Female sub-imago of *B. pumilus* ("Iron Blue Dun").
 „ 3. Female sub-imago of *B. binoculatus*, Leach ("Pale Watery Dun").
 „ 4. Female sub-imago of *B. vernus*, Curtis ("Olive Dun").
 „ 5. Male *Bibio johannis*, Meig. ("Black Gnat").
 „ 6. Female *Brachycentrus subnubilus*, Curtis, carrying green egg-sac ("Grannom").